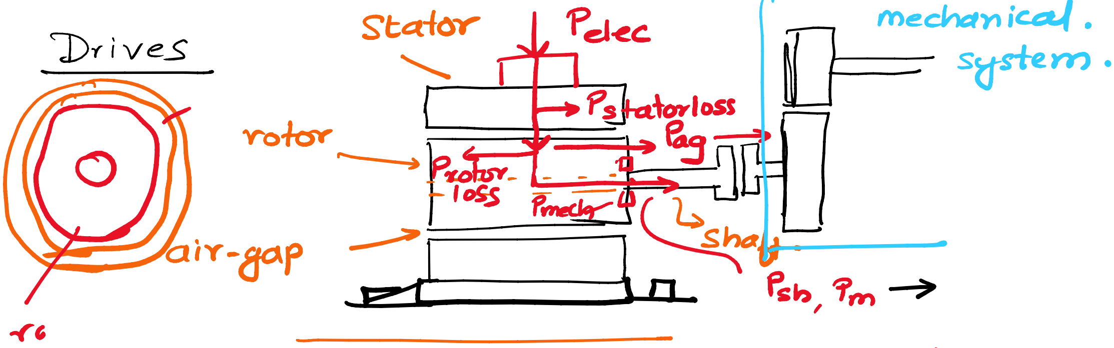
Thursday, August 24, 2023 5:58 PM

Today's class.

1. Modelling Mechanics with Drives.
2. Dynamics & stability at Equilibrium point
   what is Equilibrium point?
3. Linearization .... why?

P_{ag} = $P_{air-gap}$

Drives



electrical → circuit models
electro-mechanical.

Cross-sectional view.

Mechanics of Drive System

2 types of motion
1. Linear motion
2. Angular motion.

Linear motion

x - distance →x

$\frac{dx}{dt} = v$ — velocity

$\frac{d^2x}{dt^2} = a$ → acceleration.

θ - angle ., angular distance → $x = r.\theta$

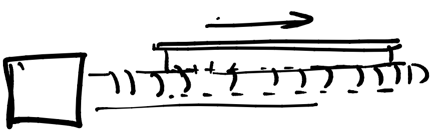
ω / Ω .. angular velocity

$v = r.\omega$

$\frac{d\theta}{dt} = \omega$ or Ω

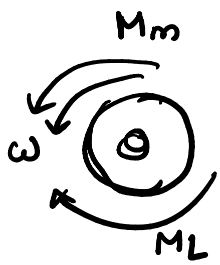
$\frac{d^2\theta}{dt^2} = \Gamma$ → angular acceleration

$a = r.\Gamma$



$M = F.r$

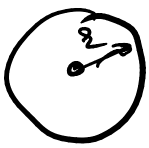
Torque / Moment



$M_A = M_m - M_L$

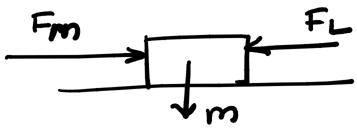
$= J.\frac{d\omega}{dt}$

Moment of Inertia



$= M.R^2$

Newton's law of motion



$F_A = F_m - F_L = m.a = m.\frac{dv}{dt}$.

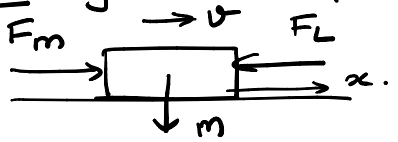
mass → inertia

Model dynamics of linear motion

F_m → v F_L

Dynamics

Model dynamics of linear motion



Dynamics

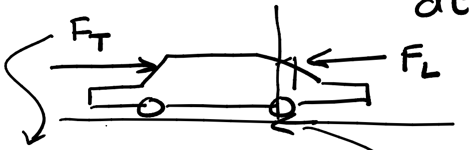
$$m.\frac{dV}{dt} = F_A = F_m - F_L$$

$$m\frac{dv}{dt} = F_x - BV$$

$$\boxed{m.\frac{dv}{dt} + BV = F_x}$$

O.D.E. First order

$$F_A = F_m - F_L = m.\frac{dV}{dt}.$$

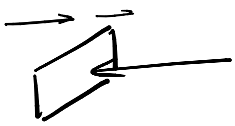


Const. velocity

$$F_L = A + Bv + Cv^2.$$

Tractive Force.

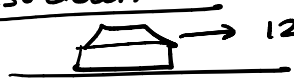
$F_A = 0$ .... $\frac{dV}{dt} = 0$ $\longrightarrow$ Rolling resistance.



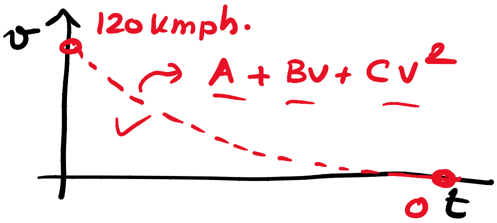
$F_D \propto v^2$

$= \frac{1}{2} c_D \rho . v^2$

Coast down test

①  120 kmph const.. over Flat road.

② Turn ... off the Engine. $F_T \rightarrow 0$ F_R. $m\frac{dv}{dt} = -F_R$



③ Measure the velocity as the vehicle comes to a stop.

Static condition Steady state condition

$\frac{d}{dt} \rightarrow 0$ $\frac{dV}{dt} = 0$ ... V - constant. $\Longrightarrow$ $F_A = 0$

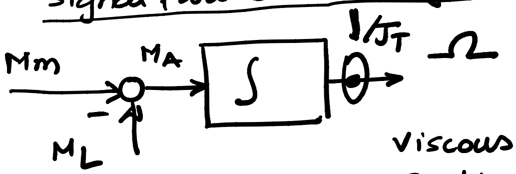
Rotational Motion.

$$J_T \frac{d\Omega}{dt} = M_A = M_m - M_L.$$

M_A: Accelerating torque. M_m: Motor torque. M_L: Load torque.

ODE --> integration

Signal flow block diagram.



Steady state condition

$M_A = 0$ $\therefore \frac{d\Omega}{dt} = 0.$

$\boxed{M_m = M_L}$ ← equilibrium

Q

$$M_L = M_{L0} + K\Omega$$

Viscous. Friction

$$\therefore J_T.\frac{d\Omega}{dt} = M_m - M_{L0} - K\Omega.$$

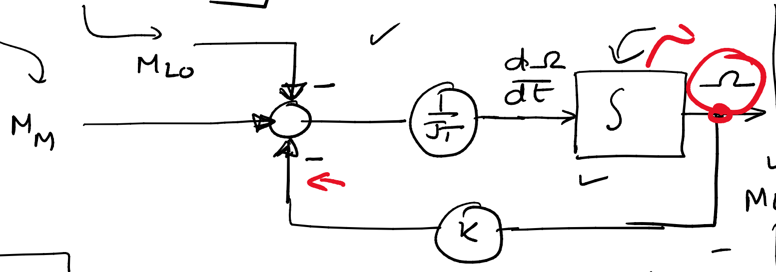
① A signal flow block diagram of the system.

② What does the system represent.

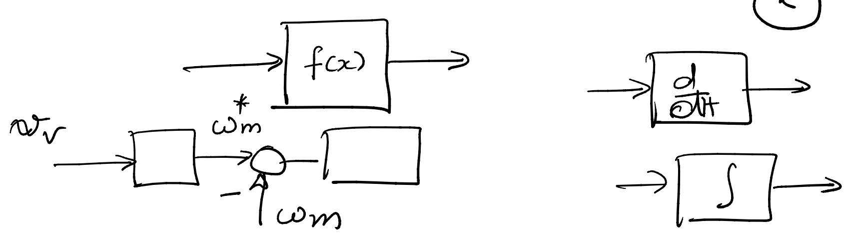
$\therefore \; J_T \cdot \frac{d\Omega}{dt} = M_m - M_{Lo} - K\Omega.$

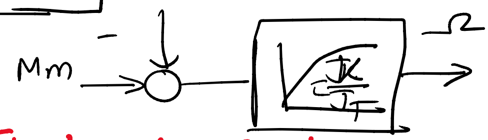
② what does the system represent.
--> guess/approximate
how Ω will vary with time.

$$\frac{d\Omega}{dt} = \frac{1}{J_T}\left[M_m - M_{Lo} - K\Omega\right]$$



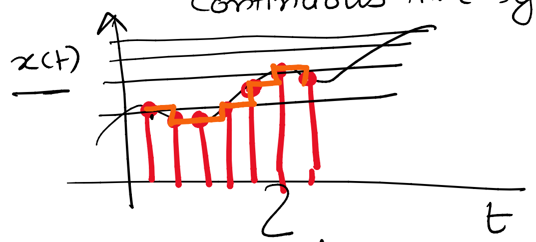
$$J_T \cdot \frac{d\Omega}{dt} + K\Omega = M_m - M_{Lo}$$





First order system
= $\int$ integrator with negative feedbac

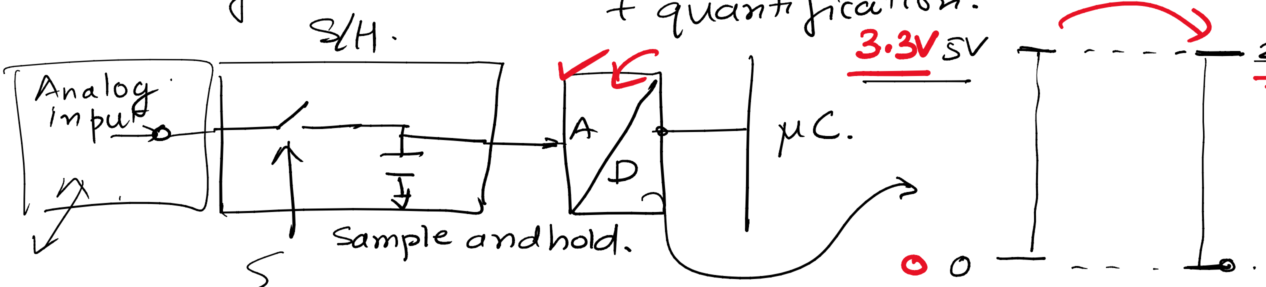
Continuous time system.



discrete-time
↳ Sampling.

digital control → discrete-time control + quantification.

S/H.

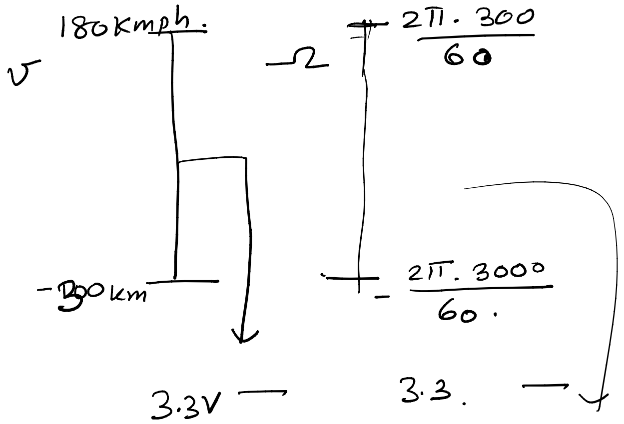


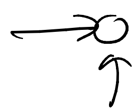
Sample and hold.

Sampling period.

8-bit -- 8051C.
32-bit STM-32

EV — 560-700 VDC





↑

Normalization — process.

$x \rightarrow$ per unit

Motor current --- rated current → 2A

80A

$$= \frac{x}{x_R} = \frac{20A}{100A}$$

$$= 0.2 \text{ p.u}$$

Maximum - RMS - current the motor can draw -- when operating at rated voltage & rated Power - 24/7 - 365 days.

Continuous rating

100A.

Base value → Maximum value of the variable that I want to measure.

360 kmph

$33^{V} \rightarrow 300$.

$$\frac{v_{actual}}{v_B} = \frac{120}{300} = 0.4$$

- 50 kmph. — o. —

↔ Units based system → per unit system.

$$J_T \cdot \frac{d\Omega}{dt} = M_A$$

[N-m]

$$\frac{[kg \cdot m^2][rad/s]}{[s]} \qquad kg \cdot \frac{m}{s^2} \cdot m$$

$M_B \leftarrow$ Base value of Torque.

$\Omega_B \Leftrightarrow$ Base value..

$s = 9.8$

$$J_T \cdot \frac{d\Omega}{dt} \frac{1}{M_B} = \frac{M_m}{M_B} - \frac{M_L}{M_B}.$$

T_m

$$\boxed{\frac{J_T \Omega_B}{M_B}} \cdot \frac{d}{dt}\left(\frac{\Omega}{\Omega_B}\right) = m_m - m_L$$

p.u.

$$\frac{kg \cdot m^2 \cdot rad / s}{kg \cdot m^2 / s^2} \quad \frac{d\omega}{dt} = m_m - m_L$$

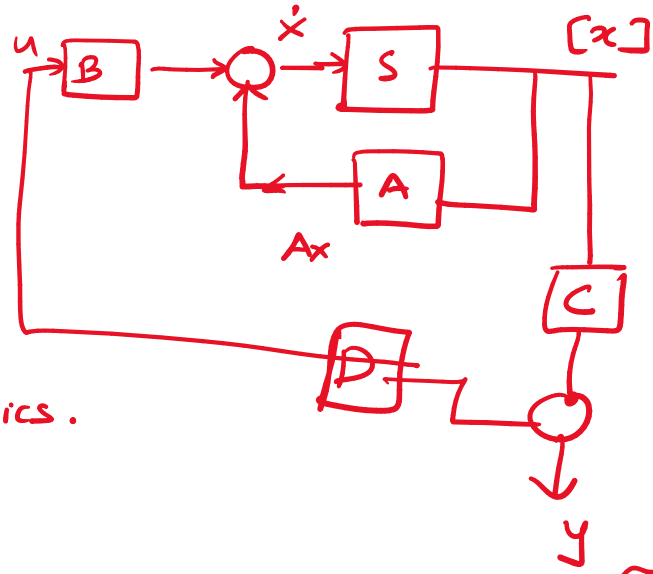
→ mechanical time constant.

p.u p.u p.u

$$T_m \cdot \frac{d\omega}{dt} = m_m - m_L$$

$[\dot{x}] = A[x] + B[u]$

$[y] = C[x] + D[u]$



① Normalization

② write equation . . . General Dynamics.

③ Steady state → $[\dot{x}] = 0$.

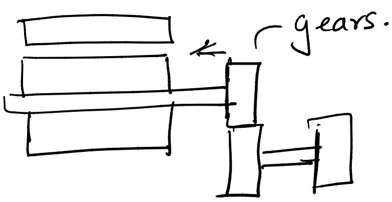
Mechanics ⟷ Model – mechanics.

Torque — M, m ~ p.u.

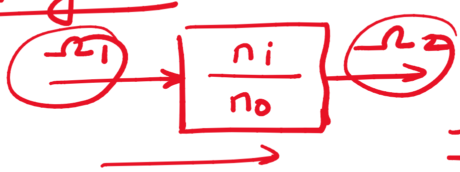
T ← time. τ – nor Constant

t ← time.

1. $T_m \cdot \frac{d\omega}{dt} = m_a = m_m - m_L$.



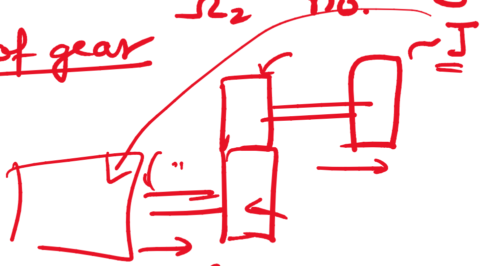
Gear System



n_g gear ratio $= \dfrac{\text{no. of rotations of driving gear } n_i}{\text{no. of rotations of driven gear } n_o}$

$\frac{\Omega_1}{\Omega_2} = \frac{n_i}{n_o} = n_g$

Conversion ratios of gear

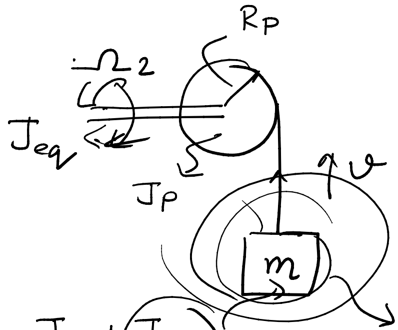


Loss less gear

$\frac{1}{2} J_{2,1} \cdot \Omega_1^2 = \frac{1}{2} J_2 \cdot \Omega_2^2$

$J_{21} = \left(\frac{\Omega_2}{\Omega_1}\right)^2 \cdot J_2$

$J_{2,1} = \left(\frac{1}{n_g}\right)^2 \cdot J_2$



$J_{eq} = J_p + J_{m,L}$

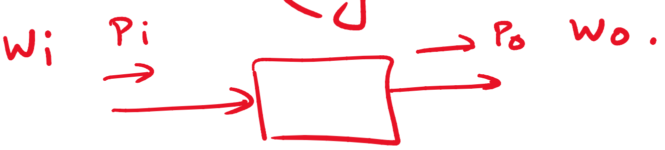
$\frac{1}{2} J_{m,L} \Omega_2^2 = \frac{1}{2} m \cdot v^2$

$v = R_p \cdot \Omega_2$

$J_{m,L} \cancel{\Omega_2^2} = m \cdot R_p^2 \cdot \cancel{\Omega_2^2}$

$J_{m,L} = m R_p^2$

$J_{eq} = J_p + J_{m,L}$



$W_i = \frac{W_o}{n_g}$

$$w_i = \frac{w_o}{\eta_g}$$

$$J_{eq} = J_p + J_{m,L}$$
$$= J_p + m R_p^2$$